Appendix A: The Visible Human Project

The panel recommends that a cooperative working group be formed from respondents to a competitive solicitation or request for proposals. The working group would be made up of representatives from several different institutions whose strengths and capabilities complement one another and make the Visible Human project feasible at a reasonable cost, with the greatest potential for widespread benefit to the biomedical community.

The working group would be formed from successful applicants who develop proposals to work on one or more of the several tasks outlined below. It is understood that no single group would necessarily perform all of the tasks working in isolation as effectively and efficiently as a cooperative group who work on various tasks and coordinate their efforts. This could be done through either a contract or grant mechanism, but it is understood that not all of the costs would necessarily be borne by the NLM. If groups had existing support for similar or related work which could be adapted to these requirements, or their institutions would co-fund and underwrite some of the development costs, this would be most effective.

Stage I: Acquisition of "Raw" Image Data

The first step avoids all issues of classification by not identifying specific objects within the image data sets. It is therefore far short of clinical application, but guarantees feasibility and reliability. It provides the "raw truth" on which all subsequent elaborations can be built.

Task 1. Obtain a set of sample adult human cadavers, three each of males and females. These cadavers must be "fresh" or very well preserved with minimal structural abnormality at the time of death. They should be young or middle-aged and fall within norms for size.

Task 2. The preparation of the bodies must be done to fulfill stringent requirements for registration of serial sections obtained by medical imaging techniques or through serial sectioning. The bodies should be prepared with injection of radiodense fluid plastic to adequately define the arterial tree and fill the major vessels. Reference markers are required in an external plaster cast which should be applied to the specimen before processing. The required

preparation is a separate task, and may be performed by specially trained experts, not necessarily from the same site which provided the cadaver initially.

Task 3. Whole body imaging of the prepared specimens is performed at 1 mm. intervals, using computed tomography of the whole body and magnetic resonance imaging of the head. This should be performed on all six cadavers soon after their demise. The cadavers should be rigidly fixed spatially prior to CT and MR imaging, such as by a total-body rigid cast, to prevent any motion or gravity-induced deformation of fresh tissues. Data from these imaging sequences would be archived to optical disks in a working group specified format that would be readable by NLM and other members of the group. All cadavers must be frozen after imaging is completed. It is anticipated that the pre-specified MRI sequences would require one or two hours of scanner time, while the CT scanning process to be performed under working group-specified conditions would require twelve hours or more, including archiving.

The working group panel would review all images from the six cadavers at a collaborative meeting and select a single male specimen and single female specimen. The four remaining specimens might be used later in whole or in part for additional subprojects, or as a potential replacement in the event of an unforeseen problem with the ones selected first.

Task 4. Anatomic sectioning would be performed at submillimeter intervals with color photographs taken at each slice level. These photographs would be obtained on pin-registered color film on as large a color transparency as possible (ideally 4 x 5 or 8 x 10 inch), and might be printed or copied as part of their distribution. The color images should be represented in an appropriate archival form, such as three color separation onto black and white film. The photographs should be made using a color film with a normal rather than enhanced color balance, such as Kodak EPN-100 Ektachrome Professional 100 ASA sheet film. This is the current standard for anatomic photography.

Task 5. The photographic images would be archived, with a recognized color standard (e.g., MacBeth, Kodak Q-60C Paper Reproduction Guide, Kodak Q-50C Kodachrome Reproduction Guide for gray scale) in each photo. These photographs would be digitized at 300 pixels/inch (professional photography/publishing resolution), or 2400 x 3000 pixels, in RGB with 12 bits per color channel (R, G and B). They would also be archived at the same pixel density as the CT slices (either 512 x 512 or 1024 x 1024) to correspond as precisely as possible with the pixels of the CT scans. This resolution can be derived from the high resolution scans without redigitizing.

All digital data would be archived to optical disks in an appropriate format; the specification of this format should be obtained by consultation with experts in computer graphics and imaging. At this point, the entire working group would have access to all slice digital data and NLM would assist with distribution of it, after suitable reformatting to video disk, CD-ROMs, or other media as deemed practical and useful. A product would be available at this stage for outside groups, as the first result from the Visible Human Project. Outside groups could obtain the serial slice images and might use them in research or teaching.

Stage II: Classification into Objects

Task 1. Object definition would be performed on the slice data with segmentation, either manually or automatically. Quality control procedures and acceptance standards for the object definition results would be established by the working group and applied to the data sets at proof of performance. The object definition task may be restricted to a single body region or organ as proposed by each respondent to the solicitation. Ultimately, the entirety of the data sets should be segmented, but it is necessary that standards be established first, and in the early work associated with this initiative, it is understood that only specialized regions may be defined.

The object definitions would be distributed in the working group specified format, and could be made available expeditiously to outside groups by the NLM. The computer software tools used to implement the object definition would be available to accompany the raw slice data and object definitions. This should facilitate the generation of additional object definitions by outside groups who are studying specific areas of the body.

Task 2. A hierarchical data base organization and associated retrieval functionality is required for the management of the very large amount of image data created in the Visible Human Project. The specification and implementation of the data base organization is a separate research task, and a successful outcome would involve a working retrieval system that operates at multiple levels and provides ties to additional sets of imagery such as nuclear medicine, ultrasound, histologic slice images, and text.

References

1. Smith, A.R.: "Geometry and Imaging: Clarifying the major distinctions between the two domains of graphics." Computer Graphics World, November 1988.

2. National Library of Medicine. Long Range Plan: Assisting health professionals education through information technology. Report of Panel 5. Bethesda, MD: U.S. Dept. of Health and Human Services, Public Health Service, National Institutes of Health; Dec. 1986. 36p.